X-Rays: A Major Cause of Cancer and Heart Disease?

Medical X-rays may be responsible for a large proportion of cancer and coronary heart disease cases.

by Peter Montague © 2000

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When Wilhelm Roentgen discovered X-rays in 1895, "doctors and physicians saw the practical potential of X-rays at once, and rushed to experiment with them".[1] Many physicians built their own X-ray equipment, with mixed results: some home-brew X-ray machines produced no radiation whatsoever; others produced enough to irradiate everyone in the next room.

The ability to see inside the human body for the first time was a marvellous, mysterious and deeply provocative discovery. Roentgen trained X-rays on his wife's hand for 15 minutes, producing a macabre image of the bones of her hand adorned by her wedding ring. Roentgen's biographer, Otto Glasser, says Mrs Roentgen "...could hardly believe that this bony hand was her own and shuddered at the thought that she was seeing her skeleton. To Mrs Roentgen, as to many others later, this experience gave a vague premonition of death," Glasser wrote.[2]

Within the year, physicians were using X-rays for diagnosis and as a new way of gathering evidence to protect themselves against malpractice suits. Almost immediately—during 1895–96—it also became clear that X-rays could cause serious medical problems. Some physicians received burns that wouldn't heal, requiring amputation of their fingers. Others developed fatal cancers.

At that time, antibiotics had not yet been discovered, so physicians had only a small number of treatments they could offer their patients. X-rays gave them a range of new procedures that were very "high tech"—bordering on the miraculous—and which seemed to hold out promise to the sick. Thus the medical world embraced these mysterious, invisible rays with great enthusiasm. Understandably, physicians at the time often thought they observed therapeutic benefits, where controlled experiments today find none. Just prior to 1920, the editor of *American X-Ray Journal* said "there are about 100 named diseases that yield favorably to X-ray treatment".

In her informative history of the technology, *Multiple Exposures: Chronicles of the Radiation Age*, Catherine Caufield (see *REHW*, nos. 200–202) comments on this period:[3] "Radiation treatment for benign [non-cancer] diseases became a medical craze that lasted for 40 or more years... [L]arge groups of people [were] needlessly irradiated for such minor problems as ringworm and acne... Many women had their ovaries irradiated as a treatment for depression." Such uses of X-rays would today be viewed as quackery, but many of them were accepted medical practice into the 1950s. Physicians weren't the only ones enthusiastic about X-ray therapies. If you get a large enough dose of X-rays, your hair falls out—so, Caufield reports, "beauty shops installed X-ray equipment to remove their customers' unwanted facial and body hair".

Roentgen's discovery of X-rays in 1895 led directly to Henri Becquerel's discovery of the radioactivity of uranium in 1896, and then to the discovery of radium by Marie Curie and her husband Pierre in 1898—for which Becquerel and the Curies were jointly awarded the Nobel Prize in 1903. (Twenty years later, Madame Curie would die of acute lymphoblastic leukaemia.)

Soon, alongside X-rays, radioactive radium was being prescribed by physicians. Radium treatments were prescribed for heart trouble, impotence, ulcers, depression, arthritis, cancer, high blood pressure, blindness and tuberculosis, among other ailments. Soon radioactive toothpaste was being marketed, then radioactive skin cream. In Germany, chocolate bars containing radium were sold as a "rejuvenator".[4] In the USA, hundreds of thousands of people began drinking bottled water laced with radium, as a general elixir known popularly as "liquid sunshine". As recently as 1952, *Life* magazine

wrote about the beneficial effects of inhaling radioactive radon gas in deep mines. Even today, The Merry Widow Health Mine near Butte, Montana, and the nearby Sunshine Radon Health Mine advertise that visitors to the mines report multiple benefits from inhaling radioactive radon,[5] even though numerous studies now indicate that the only demonstrable health effect of radon gas is lung cancer.

Thus the medical world and popular culture together embraced X-rays (and other radioactive emanations) as miraculous remedies, gifts to humanity from the foremost geniuses of an inventive age.

THE LEGACY OF "ATOMS FOR PEACE"

In the popular imagination, these technologies suffered a serious setback when atomic [and hydrogen] bombs were detonated over Japan in 1945. Even though the bombs arguably shortened World War II and saved American lives, John Hersey's description of the human devastation in Hiroshima forever imprinted the mushroom cloud in the popular mind as an omen of unutterable ruin. Despite substantial efforts to cast The Bomb in a positive light, radiation technology would never recover the lustre it had gained before WWII.

Seven years after the nuclear bombs were used in war, Dwight Eisenhower set the US Government on a new course, intended to show the world that nuclear weapons, radioactivity and radiation were not harbingers of death but were in fact powerful, benign servants offering almost limitless benefits to humankind. The "Atoms for Peace" program was born, explicitly aimed at convincing Americans and the world that these new technologies were full of hope, and that nuclear power reactors should be developed with tax dollars to generate electricity. The promise of this newest technical advance seemed too good to be true: electricity "too cheap to meter".[6]

The Atomic Energy Act of 1946 created the civilian Atomic Energy Commission, but as a practical matter the nation's top military commanders maintained close control over the development of all nuclear technologies.[7] Thus, by a series of historical accidents, all of the major sources of ionising radiation fell under the purview of people and institutions who had no reason to want to explore the early knowledge that radiation was harmful.

In 1927, Hermann J. Muller had demonstrated that X-rays caused inheritable genetic damage, and he received a Nobel Prize for his efforts. However, he had performed his experiments on fruit flies and it was easy, or at least convenient, to dismiss his findings as irrelevant to humans.

In sum, to physicians, radiation seemed a promising new therapy for treating nearly every ailment under the Sun. For the military and the Joint Commission on Atomic Energy in Congress, it unleashed hundreds of billions of dollars—a veritable flood of taxpayer funds, most of which came with almost no oversight because of official secrecy surrounding weapons development. For private-sector government contractors like Union Carbide, Monsanto Chemical Co., General Electric, Bechtel Corporation, DuPont, Martin Marietta and others, it meant an opportunity to join the elite "military-industrial complex"—whose growing political power President Eisenhower warned against in his final address to Congress in 1959.

Throughout the 1950s, the military detonated A-bombs above ground at the Nevada Test Site, showering downwind civilian populations with radioactivity.[8] At the Hanford Reservation in Washington state, technicians intentionally released huge clouds of radioactivity to see what would happen to the human populations thus exposed. In one Hanford experiment, 500,000 curies of radioactive iodine were released; iodine collects in the human thyroid gland. The victims of this experiment, mostly Native Americans, were not told about it for 45 years.[9] American sailors on ships and soldiers on the ground were exposed to large doses of radioactivity, just to see what would happen to them. The military brass insisted that being showered with radiation is harmless.

In his autobiography, Karl Z. Morgan, who served as Radiation Safety Director at the Oak Ridge National Laboratory in Clinton, Tennessee, from 1944 to 1971, recalls: "The Veterans Administration seems always on the defensive to make sure the victims are not compensated."[10] Morgan recounts the story of John D. Smitherman, a US Navy man who received large doses of radiation during A-bomb experiments on Bikini Atoll in 1946.[11]

The Veterans Administration denied any connection to radiation exposure until 1988, when it had awarded his widow benefits. By the time of his death, Smitherman's body was almost consumed by cancers of the lung, bronchial lymph nodes, diaphragm, spleen, pancreas, intestines, stomach, liver, and adrenal glands. In 1989, a year after it had awarded the benefits, the VA revoked them from Smitherman's widow.

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Starting in the 1940s and continuing into the 1960s, thousands of uranium miners were told that breathing radon gas in the uranium mines of New Mexico was perfectly safe. Only now are the radon-caused lung cancers being tallied up, as the truth leaks out 50 years too late.

In retrospect, a kind of nuclear mania swept the industrial world. What biotechnology and high-tech computers are today, atomic technology was in the 1950s and early 1960s. Government contractors spent billions to develop a nuclear-powered airplane, even though simple engineering calculations told them early in the project that such a plane would be too heavy to carry a useful cargo.[12] Monsanto Research Corporation proposed a plutonium-powered coffee pot that would boil water for 100 years without a refuelling.[13] A Boston company proposed cufflinks made of radioactive uranium for the simple reason that uranium is heavier than lead and "the unusual weight prevents cuffs from riding up".[14]

In 1957, the Atomic Energy Commission established its Plowshare Division—named of course for the biblical "swords into plowshares [ploughshares]" phrasing in Isaiah (2:4).[15] Our government and its industrial partners were determined to show the world that this technology was benign, no matter what the facts might be.

On July 14, 1958, Dr Edward Teller, "the Father of the H-bomb", arrived in Alaska to announce Project *Chariot*—a plan to carve a new harbour out of the Alaska coast by detonating up to

six H-bombs. After a tremendous political fight—documented in Dan O'Neill's book, *The Firecracker Boys*[16]—the plan was shelved. Another plan was developed to blast a new canal across Central America with atomic bombs, simply to give the US some leverage in negotiating with Panama over control of the Panama Canal. That plan, too, was scrapped.

In 1967, an A-bomb was detonated underground in New Mexico to release natural gas trapped in shale rock formations. Trapped gas was in fact released, but—as the project's engineers should have been able to predict—the gas turned out to be radioactive, so the hole in the ground was plugged and a bronze plaque in the desert is all that remains visible of Project *Gasbuggy*.[17]

In sum, according to *New York Times* columnist H. Peter Metzger, the Atomic Energy Commission wasted billions of dollars on "crackpot schemes", all for the purpose of proving that nuclear technology is beneficial and not in any way harmful.[18]

The Plowshare Division may have been a complete failure, but one lasting result emerged from all these efforts: a powerful culture of denial sank deep roots into the heart of scientific and industrial America.

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RADIATION PROTECTION STANDARDS

By 1910, in addition to X-rays, the medical community was using radioactive radium extensively for therapy. Radium was also used industrially to make glow-in-the-dark watch dials, dolls' eyes, fish bait, gun sights and other items. However, in the mid-1920s, it became clear that many young women painting radium onto watch dials were dying. In one case the employer, US Radium, in West Orange, New Jersey, insisted the women were dying because of poor personal hygiene, but studies of the workplace concluded in 1924 and 1925 that all workers were being exposed to excessive radiation.

Thus humans learned by trial and error that alpha and gamma radiation from radium can be extremely dangerous, even in small quantities.

On December 2, 1942, the first human-created nuclear reactor began operating in a secret laboratory beneath the bleachers at Stagg Field, University of Chicago. The purpose of this reactor was, first, to demonstrate that nuclear fission could be achieved (and controlled), and second, to manufacture plutonium for a bomb. Dr Arthur Compton headed this *Manhattan* Project—the code name for the US effort to make an A-bomb.

At that time, the world inventory of radium totalled about two pounds. The nuclear reactors built in Chicago, then in Clinton, Tennessee, and Hanford, Washington, would hold inventories with the radioactive equivalent of thousands of tons of radium. Many of the radioactive elements in these nuclear reactors were new, with unknown characteristics.

Arthur Compton and his colleagues insisted that safety standards had to be developed to protect workers from the harms of radiation. Early in 1943, Compton hired a radiologist, a chemist and three physicists to set radiation safety standards and to develop measuring equipment to assure that the standards were met. These five scientists were called *health physicists*—physicists concerned about health. To this day, scientists studying the health effects of radiation call themselves health physicists. X-ray specialists are called *radiologists.*

In September 1943, the initial group of health physicists moved to Clinton, Tennessee, where an enormous industrial facility was being built to process uranium; this became known as the Oak Ridge National Laboratory (ORNL). In 1944, one of the original five health physicists—Karl Z. Morgan—was named Director of the Health Physics Division at Oak Ridge, a position he held for 29 years until 1972 when he reached retirement age.[19]

Morgan played a central role in the development of the health physics profession and in setting radiation standards worldwide. The Health Physics Society was organised in 1955 with Morgan as its president pro tem; he then served as the society's first elected president in 1956–57. From 1955 to 1977, Morgan served as editor-in-chief of the society's professional journal, *Health Physics*. In 1966 an International Radiation Protection Association was established, representing professionals in 30 countries, and Karl Morgan was elected its first president.

Most radiation standards are set by the International Commission on Radiological Protection (ICRP), which in 1950 grew out of an earlier standards-setting group, the International X-ray and Radium Protection Committee. Karl Morgan served as one of the ICRP's 13 members from 1950 to 1971, and during that time he chaired the ICRP's committee on internal doses, setting radiation standards which were then adopted worldwide. It seems clear why Karl Morgan is often described as "the Father of Health Physics".

EXCESSIVE X-RAY EXPOSURE

In recent years, Karl Morgan has described and criticised the work of the ICRP. Morgan says the ICRP has suffered from two major blind spots: the Committee has never focused on harm to the public from excessive exposure to medical X-rays, and by the mid-1960s the ICRP began setting standards for radioactivity that protected the nuclear industry rather than the public. According to Morgan (who is still an emeritus member of the ICRP), the ICRP began ignoring serious radiation hazards in the early 1960s. He writes:[20]

> *The period of atmospheric testing of nuclear weapons by the United States, the United Kingdom, France and the USSR is a sad page in the history of civilised man. Without question, it was the cause of hundreds of thousands of cancer deaths. Yet there was complete silence on the part of the ICRP. During these years (1960–1965), most members of the ICRP either worked directly with the nuclear weapons industry or indirectly received most of their funding for their research from this industry. Perhaps they were reluctant to bite the hand that feeds them?*

In the 1970s, the situation grew worse after a series of studies revealed that radiation was even more dangerous than previously believed. In 1974, Baruch Modan showed that a woman's chances

of breast cancer were increased by X-ray doses as low as 1.6 rem.[21] In 1977, Thomas Mancuso and others reported that workers at the Hanford plutonium facility were dying of cancers from radiation doses as low as 3 rem, accumulated over many years.[22] (The worker safety standard at the time was 5 rem per year.)

Karl Morgan says these studies threw the nuclear industry into a panic. "Concerned that its very existence was threatened if the public believed that there was an increased risk of cancer at these low levels of exposure, the nuclear-industrial complex determined that it would respond vigorously to all challengers," Morgan reports in his autobiography.[23] As a result, "...health physics in recent decades has sacrificed its integrity. Certainly there remain some true professionals who will not shade the truth to appease their employers, but they are in the minority," Morgan said in 1999.[24]

The ICRP turned a blind eye to other problems affecting public health: excessive exposures from medical and dental X-rays. Early in the 1950s, a series of studies had shown that X-rays were more dangerous than previously known. In 1950, H.C. March showed that radiologists were nine times as likely as other physicians to die of leukaemia.[25] In 1956, Alice Stewart showed that a single X-ray of a foetus in the womb would double the likelihood of childhood leukaemia.[26]

In his 1999 autobiography,[27] Morgan refers to his 1994 description of the ICRP's failure to concern itself with excessive and unnecessary X-ray exposures from diagnostic procedures:[28]

...it was like running into a brick wall every time I raised the question of excessive and unnecessary X-ray diagnostic exposures... I soon became convinced that the subject of excessive medical exposure was a no-no with ICRP because ICRP was founded under the auspices of the International Congress of Radiology (ICR) and radiologists did not want any restraints or interference in their use of diagnostic X-rays. I had the uncomfortable feeling that there was a serious conflict of interest with ICR sponsorship of ICRP... Conflict of interest seems to be a contagious and virulent disease.

In the mid-1960s, Morgan's division of the Oak Ridge Laboratory studied the X-ray doses being received by US children as a result of a mass chest X-ray program. Starting in the 1950s, portable X-ray machines in special trucks were brought to schools, and hundreds of thousands of US children were given chest X-rays. The Oak Ridge study found that each of these children was receiving an X-ray dose of 2 to 3 rem; Morgan knew this was excessive because workers at the Oak Ridge Laboratory were getting a dose of only 0.015 rem from a chest X-ray. In other words, children were getting a dose of X-rays 130 to 200 times as high as the dose needed to produce an adequate X-ray film—not to mention that most of the children did not need a chest X-ray at all. (The mass X-raying of US children was stopped by a campaign led by Morgan, Rosalie Bertell, Irwin Bross and others.)[29]

In the 1940s and 1950s, many shoe stores installed fluoroscopic (X-ray) shoe-fitting machines. By 1949, a study had shown that shoe-fitting machines were giving children high doses of radiation. Again, the ICRP showed no interest in the subject.

Morgan and his colleagues calculated that medical X-rays accounted for 90 per cent of all radiation from human-created sources.[30, 31] Morgan showed in 1963 that the average US citizen was receiving each year about as much radiation from medical X-rays as from natural background sources. In other words, the use of medical X-rays was doubling the average person's exposure to radiation in the US. Morgan's point was that the same benefits could be achieved at much lower doses by using up-to-date equipment and techniques. The medical community, for the most part, turned a deaf ear.

For many years, Morgan and others wrote about the hazards of excessive and unnecessary radiation exposures from medicine and dentistry—an effort he describes as "twenty years of frustrating failures". In his autobiography, Morgan says it was "a highlight of my life's work"[32] when President Lyndon Johnson signed Public Law 90-602, the "Radiation Control for Health and Safety Act of 1968", which set minimum federal standards for X-ray equipment (see www.fda.gov/cdrh/radhlth/-summary.html). However, the law can do nothing to curb unnecessary and excessive X-ray exposures, which still occur routinely.

Gofman believes that medical X-rays are the major cause of cancer (including breast cancer) and heart disease in the US.

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MEDICAL X-RAYS, CANCER AND HEART DISEASE

For the past 20 years, another important scientist concerned about excessive exposure to X-rays has been Dr John Gofman. In his autobiography, Morgan describes Gofman this way:[33]

...John Gofman, a scientist who [holds] degrees in both chemistry and medicine. Along with Glenn Seaborg, Gofman co-discovered uranium-233, and he also was the first one to isolate plutonium. In spite of these achievements, Gofman has yet to receive the recognition due him; in my opinion, he is one of the leading scientists of the twentieth century.

For 20 years or more, Gofman has been publishing studies of the hazards of low-level radiation. His latest book fills 700 pages addressing this hypothesis: "Medical radiation is a highly important cause (probably the principal cause) of cancer mortality in the United States during the twentieth century."[34] In other words, Gofman believes that medical X-rays are the major cause of cancer (including breast cancer) and heart disease in the US. Gofman's work is careful, thorough and clearly written, so most of the health physicists of this world probably cannot be expected to take it lying down.

John Gofman is a medical doctor with a PhD in nuclear and physical chemistry. He is Professor Emeritus of Molecular and Cell Biology at the University of California, Berkeley, and a member of the faculty at the University of California Medical School at San Francisco. During his long career, he has pursued two separate fields of research: heart disease, and the health

effects of low-level radiation. He has won several awards for original research into the causes of atherosclerosis, which is the growth of fatty "plaque" inside the blood vessels, often causing fatal heart attacks. In 1974, the American College of Cardiology selected him as one of the 25 leading researchers in cardiology of the past quarter-century.

In the early 1960s, the US Atomic Energy Commission (AEC) asked Gofman to develop a Biomedical Research Division at the AEC's Livermore National Laboratory (LNL), to evaluate the health effects of all types of nuclear activities. In 1970, he became convinced that radiation was more dangerous than previously believed, and he spoke out against Project *Plowshare* (the AEC's plan to explode hundreds of nuclear weapons to release gas trapped in rock beneath the Rocky Mountains and to excavate new harbours and canals by exploding nuclear bombs above ground). He also called for a five-year moratorium on the AEC's plan to develop 1,000 commercial nuclear power plants.

By 1974, Gofman's government funding was cut. He then began a series of books on the dangers of radiation: *Radiation and Human Health* (1981); *X-Rays: Health Effects of Common Exams* (1985); *Radiation-induced Cancer From Low-Dose Exposure: An Independent Analysis* (1990); *Preventing Breast Cancer: The Story of a Major, Proven, Preventable Cause of This Disease* (1995, 2nd ed. 1996); and *Radiation from Medical Procedures in the Pathogenesis of Cancer and Ischemic Heart Disease* (1999).[35, 36, 37, 38, 39]

Gofman is a superb teacher. In his books, he explains the raw data, where it came from, its shortcomings, how it might be improved (or why we're stuck with what we've got). Then he moves the reader step by step towards his conclusions, explaining each step for the novice as well as the expert. When he is forced to make assumptions, he explains why he thinks he is making the right ones. He often describes alternative assumptions and the effect they would have on his conclusions. Nothing of importance is omitted. As a result, Gofman's books are lengthy—typically 500 to 900 pages filled with tables of data accompanied by detailed explanations. The reader gets a thorough education in the topic, satisfactory for both novice and professional. I consider Gofman one of the greatest teachers of the 20th century. His work has already changed the way the world views the dangers of radiation, and his latest book will—eventually, after a long fight—revolutionise the way the world looks at medical radiation. His work will save, cumulatively, tens of millions of lives.

In his latest (1999) book, Gofman presents strong evidence that medical radiation is a major cause of cancer *and* of atherosclerosis (coronary heart disease).[40] By "medical radiation", Dr Gofman is referring mainly to X-rays, including fluoroscopy and CT ("CAT") scans. The mechanism is simple to state: radiation causes genetic mutations which eventually give rise to disease.

What is Gofman saying? Does he mean that medical radiation is necessarily the *only* cause of cancer and coronary heart disease? Certainly not. Does he mean that cancer is *not* caused by smoking, poor diet, genetic inheritance, pesticides, diesel exhaust, dioxin and toxic chemicals encountered on the job? Certainly not. Cancer and heart disease both have multiple causes. For a cancer (or an atherosclerotic plaque) to develop, a cell must undergo several (probably 5 to 10) separate gene mutations. Some of these mutations might be inherited, but most occur from exposure to gene-damaging substances in the environment.

Here is a way to understand multiple causation. Gofman gives the following hypothetical example of 100 cases of cancer:

- 40 cancers caused by co-action of X-rays + smoking + poor diet;
- 25 cancers caused by co-action of X-rays + poor diet + inherited genetic mutations;
- 25 cancers caused by co-action of X-rays + smoking + inherited genetic mutations;
- 10 cancers caused by co-action of smoking + poor diet + inherited genetic mutations.

In the first case, the 40 cancers are caused by genetic mutations that are, in turn, caused by X-rays, smoking and poor diet. Each of these three factors is necessary for the cancer to occur; if any one of the three factors is missing, the cancer will not occur.

We can see in this example that X-rays contribute to 40 + 25 + 25 = 90 cases out of 100. In this example, if X-rays were not present, 90% of the cancers would not occur. Now, in the same example, look at poor diet. Poor diet contributes to 40 + 25 + 10 = 75 of the 100 cases. If poor diet were not present, 75% of the cancers in this example would not occur.

Gofman calculates that in 1993, 50% of all cancers in women and 74% of all cancers in men were attributable to X-rays.

In other words, about 60% of all cancers in the US in 1993 were attributable to X-rays.

We can see in this example that we have X-rays "causing" 90% of the cancers—"causing" in the sense that the cancers wouldn't occur in the absence of X-rays. But we also have poor diet "causing" 75% of the same cancers, meaning that 75% of the cancers wouldn't occur in the absence of poor diet.

Thus we can see that when Gofman says X-rays are responsible for a large proportion of all cancers in the US, he is *not* saying that X-rays are the *only* cause of those cancers. However, he *is* saying that most of those cancers would not occur in the absence of X-rays.

It is important to point out that Gofman is not opposed to medical X-rays. Rather, he is opposed to *unnecessary exposures* from X-rays. He has shown over the years—and he is definitely not alone in this—that medical X-ray exposures in the US could be cut by at least 50% with no loss of medical information. The careful use of modern X-ray equipment and techniques can reduce X-ray exposures by half (or more) without sacrificing any medical benefits. Thus, at least half the cancers caused by medical X-rays are completely unnecessary.

How many unnecessary cancers are we talking about? Gofman calculates that in 1993, 50% of all cancers in women and 74% of all cancers in men were attributable to X-rays. In other words, about 60% of all cancers in the US in 1993 were attributable to X-rays. About 500,000 people die of cancer each year in the US. If 60% of these deaths are attributable to X-rays and half are unnecessary, we are talking about 150,000 unnecessary cancer deaths each year in the US.

Gofman calculates that the proportion of coronary heart disease (CHD) attributable to X-rays is slightly higher than the proportion of cancers. Among men in 1993, 63% of CHD deaths were attributable to X-rays, and 78% among women. So, in rough numbers, 70% of CHD deaths are attributable to X-rays, Gofman believes. Since CHD caused roughly 460,000 deaths in the US in

1993, then, if Gofman is right, 70% (or 322,000) of these deaths are attributable to X-rays and half of these (or 161,000) are unnecessary.

Thus we can see that X-rays are responsible for about 150,000 + 161,000 = 311,000 unnecessary deaths each year in the US, if Gofman is right.

Gofman's study takes a novel approach, avoiding certain difficulties inherent in all data linking medical radiation to health. Here are the difficulties. Firstly, there are no reliable estimates of the average per-capita radiation dose that the US population receives now, or has received in the past, from medical X-rays. (Gofman explains why in chapter 2.) Secondly, there are no reliable estimates of the cancer risk per unit dose from medical X-rays because no one is sure of the precise exposures received by various groups that have been studied for cancer effects. (Again, see Gofman's chapter 2.)

Avoiding these difficulties, Gofman developed a novel approach. He found disease statistics for the entire US population, broken down into nine census districts (1940 to 1990 for cancer, and 1950 to 1990 for coronary heart disease). Then he correlated these disease statistics, year by year, to the number of physicians per 100,000 population in each of the nine census districts. The density of physicians per 100,000 population provides a *relative* measure of the medical radiation per 100,000 population in the nine districts, year by year.

Gofman has shown that cancer death rates *rise* in lock-step with increasing density of physicians in a census district, while non-cancer deaths *decline* in lock-step with increasing density of physicians per 100,000 population, *except* in the case of coronary heart disease (CHD) which follows the rising pattern of cancer. Thus, Gofman's hypothesis, that CHD is linked to medical radiation, "fell out of the data". Because he had decades of experience researching the causes of CHD (he has written three books on heart disease), and because he knows the radiation literature so well, Gofman was able to put two and two together: radiation induces mutations in the coronary arteries, giving rise to what he calls "dysfunctional clones" (mini-tumours) in the smooth muscle lining the arteries.

Interestingly, using his "physician density" method, Gofman estimates that medical radiation caused 83% of female breast cancer in the US in 1993. Using a completely different method, Gofman estimated in 1995 that medical radiation was responsible for 75% of US breast cancer. The two estimates, by two completely different methods, are remarkably similar.

MINIMISING X-RAY EXPOSURE

It will not be easy to convince physicians to take special care to minimise radiation administered to their patients. Familiarity breeds contempt, and many physicians and dentists treat X-rays as if they are entirely harmless.

Recently I broke a tooth. My dentist, who is first rate, needed to document the injury for insurance purposes. "I'll just snap an X-ray," he said. I asked, "Is there some other way?" He nodded and immediately scribbled a note: "I broke my tooth and I don't want an X-ray." "Sign this," he said. "The insurance company is required to accept it." One unnecessary X-ray avoided.

Next time someone says they're going to give you an X-ray, don't put them on the spot but mention that you're curious what dose of radiation you will get. If your experience is anything like mine, the person giving the X-ray will not know the answer and will tell you: "Don't worry. It's completely safe."

But it's not. ∞

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